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SHIFTS IN SHUTTLE SRM PERFORMANCE BECAUSE OF AMMONIUM PERCHLORATE CRYSTAL SHAPE ON MISSIONS 51-I/J AND 61-A/B

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ABBREVIATIONS AND ACRONYMS

AGT	Adaptive Guidance Throttling
AMCT	Average Mix Cast Time
AP	Ammonium Perchlorate
BARF	Burn Anomalous Rate Factor
CEI	Contract End Item
F	Fahrenheit
HPM	High Performance Motor
IPS	Inches Per Second
ISP	Specific Impulse
JSC	Johnson Space Center
KM	Kerr McGee
LH	Left Hand
MET	Mission Elapsed Time
MIN	Minute
MSFC	Marshall Space Flight Center
MTI	Morton Thiokol Incorporated
PE	Pacific Engineering (PEPCON)
PMBT	Propellant Mean Bulk Temperature
PSI	Pounds Per Square Inch
QM	Qualification Test Motor
RH	Right Hand
SEC	Second
SRM	Solid Rocket Motor
SSME	Space Shuttle Main Engine
STS	Space Transportation System
I_{20}	Total Impulse Accumulated at 20 sec
IP_{20}	Total Head Pressure Integral at 20 sec

TECHNICAL MEMORANDUM

SHIFTS IN SHUTTLE SRM PERFORMANCE BECAUSE OF AMMONIUM PERCHLORATE CRYSTAL SHAPE ON MISSIONS 51-I/J AND 61-A/B

I. SUMMARY

Based upon the evaluations of the Shuttle flights designated as Missions 51-I and 51-J, the SRM and Systems Performance Groups at MSFC, JSC, Morton Thiokol, and Rockwell International, became concerned about the trends in SRM performance. The observed SRM performance for these flights are unusually higher than predicted, particularly in the first 20 sec. Although the SRMs continued to perform within specification limits, the new higher levels needed to be understood. This understanding was needed to assure that this deviation from performance would not get worse. Because these SRMs were produced from high viscosity propellant manufactured from ammonium perchlorate (AP) supplied by Pacific Engineering (PE), several studies were performed using this propellant data. The results of these studies to isolate potential causes are presented. Predictions for the subsequent flights (Missions 61-A/B/C) are provided. Evaluations of the quality of these flight predictions are shown.

II. INTRODUCTION

The Space Shuttle Booster consists of two SRMs which provide thrust during the liftoff phase of flight and through the lower atmosphere. The performance of each SRM on each flight is individually predicted and evaluated with respect to various flight performance criteria. Any differences in observed performance from predicted performance is analyzed to verify booster capability for the next flight.

The observed SRM performance is available from 25 flights. Seven flights (STS-1,...,STS-7) used the standard motor configuration. The remaining 18 flights (STS-8 through STS-33) were manufactured and flown using the HPM configuration. The HPM configuration was developed to supply additional payload capability above the standard SRM capability. This report does not include information from the SRMs used on STS-33 (Mission 51-L).

The excellent reproducibility of the 24 HPM SRMs used during the 12 flights [STS-8 through STS-26 (Mission 51-F)] is shown to provide a basis for comparison. The transient phenomena in the first 20 sec of flight, which initiated the investigation, is shown for Missions 51-I/J (STS-27/28). The results of the propellant characteristics investigation are shown with the resulting correlation with large motor burn rate scale factor, ISP, and the first 20-sec time interval. Comparisons of the predicted and reconstructed data for the next three flights are discussed which support the crystal shape hypothesis.

III. NOMINAL SHUTTLE SRM PERFORMANCE

A. Discussion

The SRM performance which is designated as nominal was derived from qualification test and flight data for the HPM SRM. This nominal is based on data from nine normally processed SRMs on the flights of STS-8, 9, 11, 13, 14, and the QM-4 static test. This test/flight data was used as a basis for the population block prediction model designated as TC-271-84. This model was used to update the specifications and to be the standard for future HPM SRM performance comparisons and assessments.

B. Thrust-Time Shape Reproducibility Requirements

The thrust-time shape reproducibility requirements are documented in the SRM CEI Specification [1] and in JSC 07700, Volume 10 [2]. These documents require the thrust-time trace produced by the HPM SRM's when defined at the target burn rate of 0.368 ips (625 psia) and PMBT of 60°F to be within ±3 percent of the nominal. This set of limits is shown on Figure 1. In addition, the integral of the HPM SRM thrust-time trace at different times is to be within certain limits or gates as follows:

- Minimum Impulse at 20 sec = 63.1 million lb-sec
- Minimum Impulse at 60 sec = 171.2 million lb-sec
- Maximum Impulse at 60 sec = 178.1 million lb-sec
- Minimum Impulse at action time = 293.8 million lb-sec.

Since the implementation of Adaptive Guidance Throttling (AGT) on STS-8, the desired thrust-time shape reproducibility requirement is essentially zero variation. Variations in thrust-time shape can cause non-optimum AGT software responses. The AGT software must decide at approximately 20 sec (MET) if the future flight course and SSME power level during the upcoming Max Q period must be revised. AGT makes this decision by the performance up to approximately 20 sec. If the first 20-sec portion of the thrust-time trace is lower/higher than predicted, a new pitch attitude profile and SSME power level is computed to overcome the low/high SRM performance over the remainder of the SRM burn. If different than predicted, the AGT software, because of its design, assumes that the different performance means different SRM burn rate. No thrust trace shape variation is assumed in AGT operation planning. On the recent missions when the thrust-time trace shape was higher than predicted, AGT throttled down the SSMEs and lofted the vehicle expecting a higher SRM burn rate. Then, the actual first stage performance was low because all of the expected higher burn rate did not appear. Yet, the SRM had performed at a higher level than predicted and was still within requirements.

C. STS-8 Through STS-26 Experience

The Shuttle SRM thrust-time shape performance has been reconstructed from each of the 12 flights from STS-8 through STS-26 (Mission 51-F). These flights demonstrated excellent reproducibility by delivering near-normal performance. Individual flight/test thrust-time traces from the HPM SRMs were normalized to the burn rate of 0.368 ips, PMBT = 60°F and averaged. The average is compared to the ±3 percent limits on Figure 1. The impulse values for this average are compared to the requirements on Table 1.

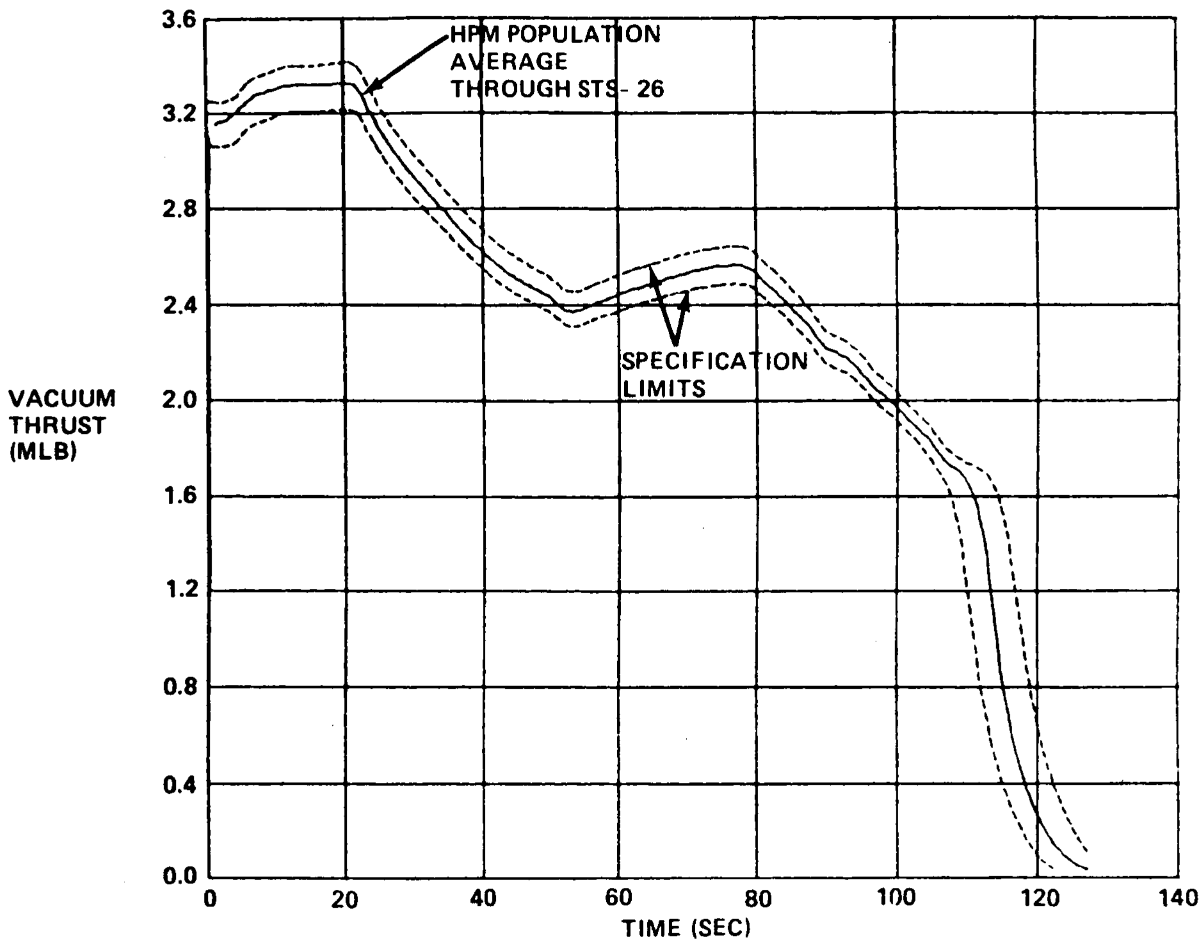


Figure 1. Comparison of HPM population vacuum thrust (averaged through STS-26) to specification limits.

TABLE 1. HPM POPULATION AVERAGE VACUUM IMPULSE GATE COMPARISON TO REQUIREMENTS

Gate	Requirement*	HPM Population Average Through STS-26**
I_{20} (10^6 lb-sec)	63.1 (Minimum)	64.68
I_{60} (10^6 lb-sec)	178.1 (Maximum) 171.2 (Minimum)	173.03
$I_{Action\ Time}$ (10^6 lb-sec)	293.8 (Minimum)	296.46

* JSC 07700, Volume 10, Appendix 10.12, Figure 4.6.

** HPM thrust-time traces normalized to burn rate of 0.368 ips, PMBT = 60°F.

IV. SHIFTS IN SHUTTLE SRM PERFORMANCE

A. Discussion

Based upon the evaluation of recent flight experience (Mission 51-I/J) designated as STS-27/28, the observed SRM performance has been much higher than predicted during the first 20 sec. There are two contributors to this higher-than-usual performance. The higher performance can result from higher-than-predicted propellant burn rates and higher-than-normal thrust-time trace shapes. The flight burn rates on Mission 51-I and 51-J are the highest experienced to date. The burn rates were predicted to be higher-than-usual due to high values of small motor (5 in CP) burn rate data. Since the reconstructed burn rates were even higher than these predictions, the SRM large motor scale factors derived for these flights were also higher than the average prediction scale factor. The actual and predicted average burn rates for STS-27/28 at PMBT = 60°F are compared to the target burn rate for each flight on Figure 2. This figure compares the entire flight population of predicted and actual flight burn rates to the target burn rate at a PMBT of 60°F. After removing the effect of different burn rates by normalizing the thrust-time traces to a burn rate of 0.368 ips and PMBT = 60°F, the thrust/pressure traces for flights STS-27/28 have higher-than-usual shapes in the critical first 20-sec region.

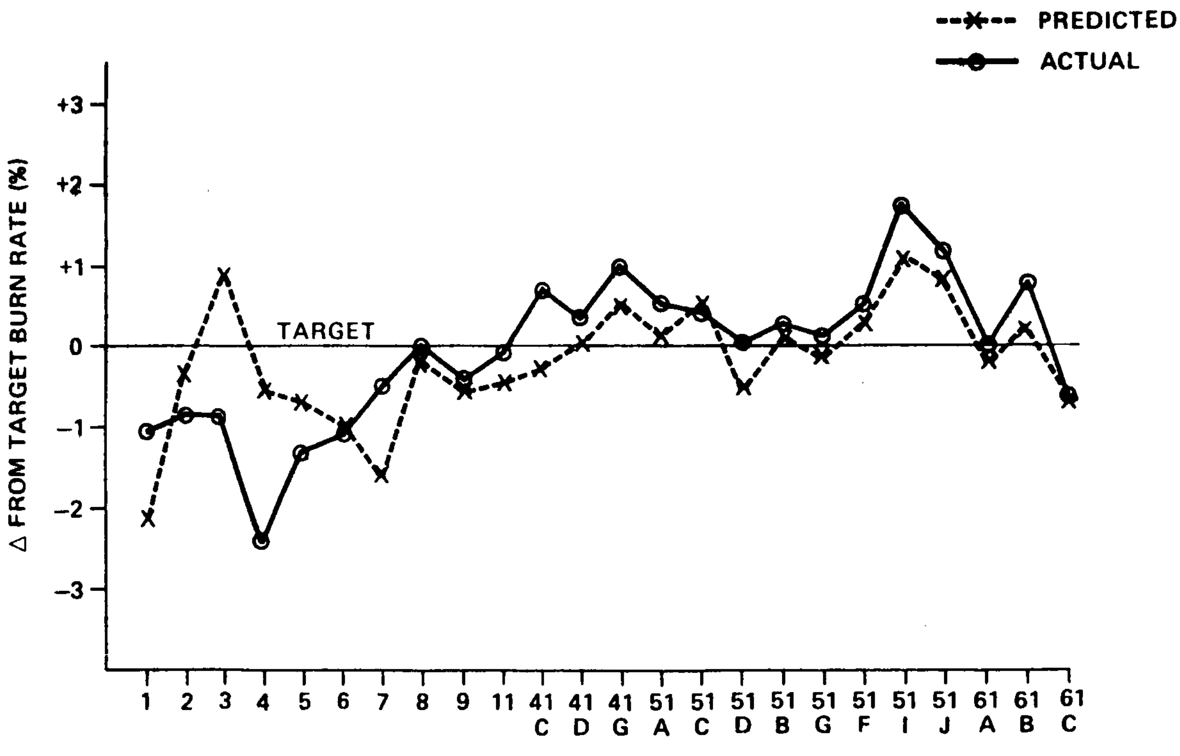


Figure 2. Comparison of actual, predicted, and target burn rates, PMBT = 60°F.

B. Missions 51-I/J High Thrust Level in First 20 Sec

During the postflight evaluation of STS-27 (Mission 51-I), the analysis of the thrust-pressure data indicated that the thrust-time performance continued to be within past flight performance. Figure 3 shows the normalized average head pressure trace for the left and right motors during the first 20 sec for STS-27. The trace is compared to the nine-motor population average at a burn rate of 0.368 ips and PMBT = 60°F. The total impulse through 20 sec (I_{20}) of the SRM set SRM-20 used on STS-27 (51-I) is shown with respect to all flights since STS-8 on Figure 4. The I_{20} values for each flight are compared to the 9 motor population average. The I_{20} level was noted as higher than nominal on STS-27, but similar to the previous flight. In addition, STS-27 was lower than the previous worst case experience on STS-24 (Mission 51-B). On STS-28 (Mission 51-J), the quick-look analysis of thrust/pressure performed on the day-of-launch indicated something unusual had occurred. The thrust/pressure levels through 20 sec were much higher than predicted. The difference between predicted and actual head pressures for STS-28 during the first 20 sec period are shown on Figures 5 and 6 for the left and right motors, respectively.

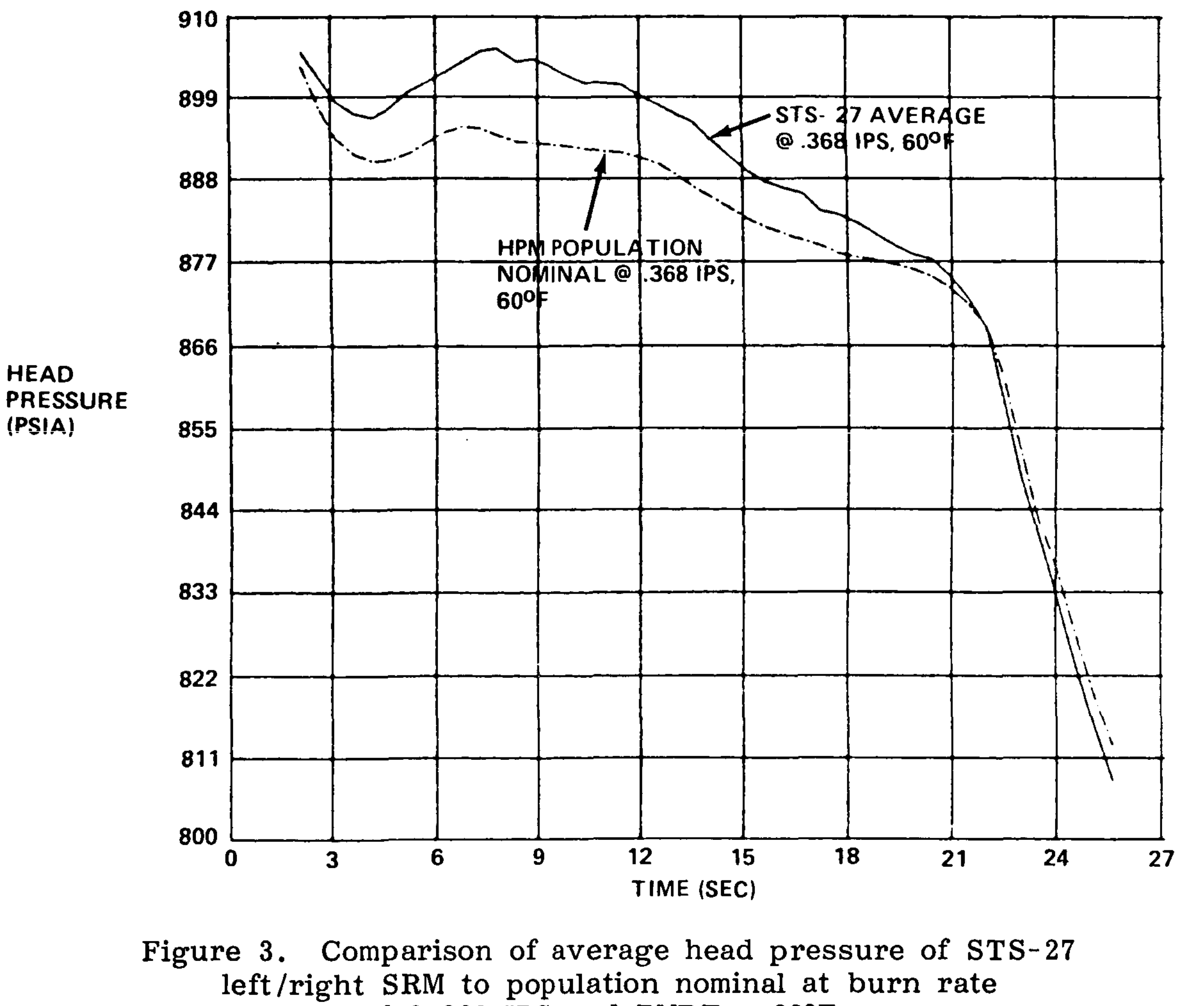


Figure 3. Comparison of average head pressure of STS-27 left/right SRM to population nominal at burn rate of 0.368 IPS and PMBT = 60°F.

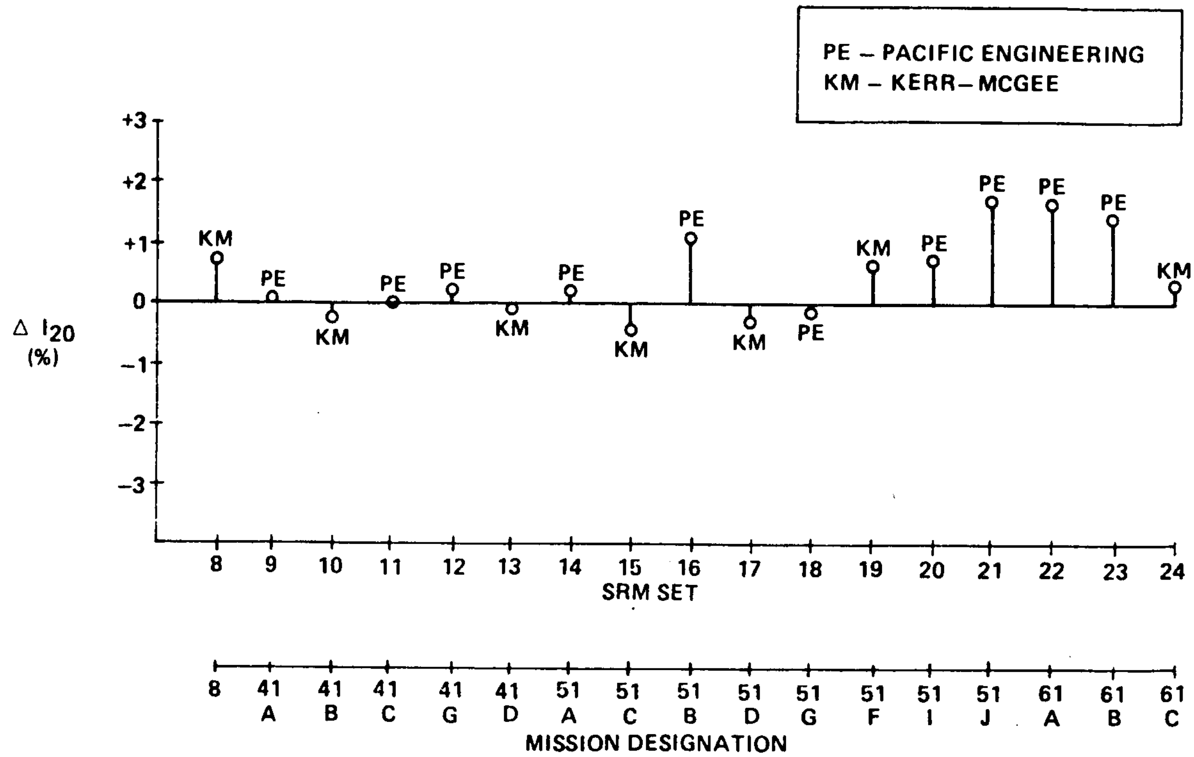


Figure 4. Comparison of flight average 20-sec impulse (I_{20}) normalized to burn rate of 0.368 ips, PMBT = 60°F to nominal impulse at 20 sec.

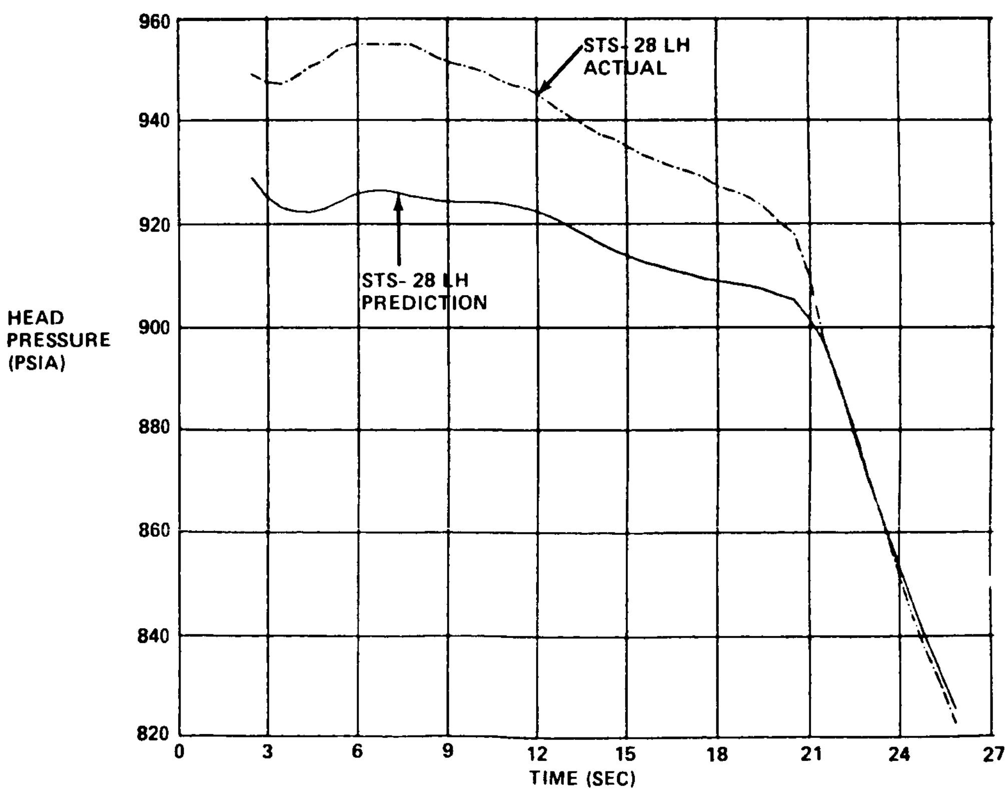


Figure 5. STS-28 (Mission 51-J) comparison of predicted and actual head pressure for left SRM.

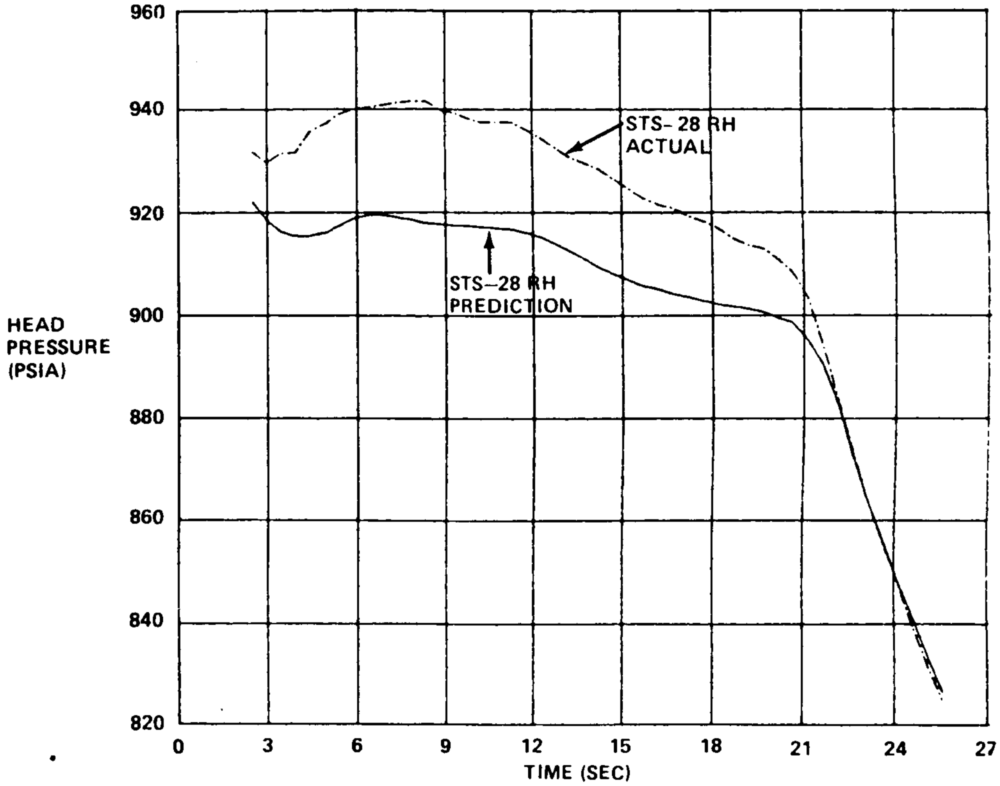


Figure 6. STS-28 (Mission 51-J) comparison of predicted and actual head pressure for right SRM.

The flight average burn rates on STS-27/28 were and continue to be the highest burn rates experienced to date as shown on Figure 2. The predicted burn rates were also higher than usual due to higher burn rates derived from the 5 in CP small motors cast from propellant samples. The higher-than-predicted burn rates exaggerated the difference between predicted and actual thrust/pressure data during the first 20 sec period.

After normalizing the STS-28 (Mission 51-J) thrust/pressure data to the target burn rate of 0.368 ips and PMBT = 60°F, the thrust/pressure was still unusually high in the critical first 20 sec region compared to previous flight experience. This difference indicated that a major shift in thrust/pressure shape had occurred. The average STS-28 value for I_{20} was $\sim$1.6 percent higher than the 9-motor population average. The previous worst case for I_{20} was $\sim$1.0 percent on STS-24 (Mission 51-B). The comparison of I_{20} values on Figure 4 for STS-28 (Mission 51-J) to earlier flights clearly indicated that the SRM performance on Mission 51-J was unusual. Because of the differences in STS-27/28 from previous flights, an investigation was begun by the MSFC, Morton Thiokol, and Rockwell SRM performance groups to explain the sudden shift in performance. Assistance was solicited from the SRM Chief Engineer's office at MSFC and from project engineers at the Wasatch Division of Morton Thiokol Incorporated.

C. Propellant Investigation

1. Mission 51-I/J SRM Propellant

The deviations in the STS-27/28 (Mission 51-I/J) SRM performance from nominal were investigated after the differences in burn rate were removed. Since the thrust/pressure variation occurs early in the motor burn (approximately first 20 sec) this eliminates potential problems with case size/ovality, throat erosion, and abnormal propellant temperatures at the case wall. The interior dimensions of the propellant are rigidly controlled by mandrel/core alignment and mandrel refurbishment requirements. The propellant casting apparatus and propellant formulation were unchanged for these SRMs. The remaining variable for investigation is propellant raw materials.

The SRM set designated as SRM-21 was used on STS-28 (Mission 51-J). This set of SRMs was known to be cast from propellant which was much more viscous than normal. This high viscosity was first observed in the very low propellant rise rates in the first SRM segment being cast for SRM-21. The propellant rise rates are monitored because of their importance in minimizing the formation of voids or bubbles in the propellant. The SRM-21 set was cast from two batches of raw materials instead of one batch because of this viscosity problem. The SRM-21 set contains two segments cast from raw materials purchased for the SRM-22 set. These segments were cast with SRM-22 raw materials because the SRM-22 viscosity was lower than SRM-21. This substitution into the LH forward center and RH forward segments allowed MTI to continue motor manufacture while researching the viscosity problem.

The propellant viscosity investigation at MSFC and MTI was closely followed to determine if the cause of increased viscosity might also be related to the unusual shifts in the thrust-time traces. Data were generated by MTI on all raw materials used to manufacture the propellant. These data were critiqued to isolate the most likely candidates for statistical study.

2. Ammonium Perchlorate Crystal Differences

The general plan for SRM propellant casting assumes that the propellant for the two SRMs on each flight will be manufactured from the same batch of raw materials. These raw materials are alternately purchased from at least two vendors to assure second-source capability. The ammonium perchlorate (AP) is purchased from either Kerr McGee (KM) or from Pacific Engineering (PE). The AP vendor for flights STS-8 through STS-36 is shown on Table 2. This table shows flight number, mission, SRM set number, AP vendor, and average mix cast time (AMCT). The table shows that the SRM's used on STS-27/28 (Missions 51-I/J) were manufactured from AP supplied by PE. In addition, the SRMs for the next two flights (61-A/B) were manufactured with AP supplied by Pacific Engineering.

The propellant viscosity issue was pursued vigorously by MSFC and MTI in concert with the raw material suppliers. This review confirmed that all materials supplied to MTI complied with the raw material specifications. However, subsequent investigation by MTI using photomicrographs uncovered the fact that the AP crystals in the more viscous propellant had different shapes than previous batches. The crystals from KM and PE are compared for two mesh screen sizes on photomicrographs on Figures 7 and 8, respectively. The AP provided by KM is much smoother and rounder than the AP provided by PE. These PE crystals are multi-particles with irregular shapes, whereas they were previously smooth and round. PE has isolated

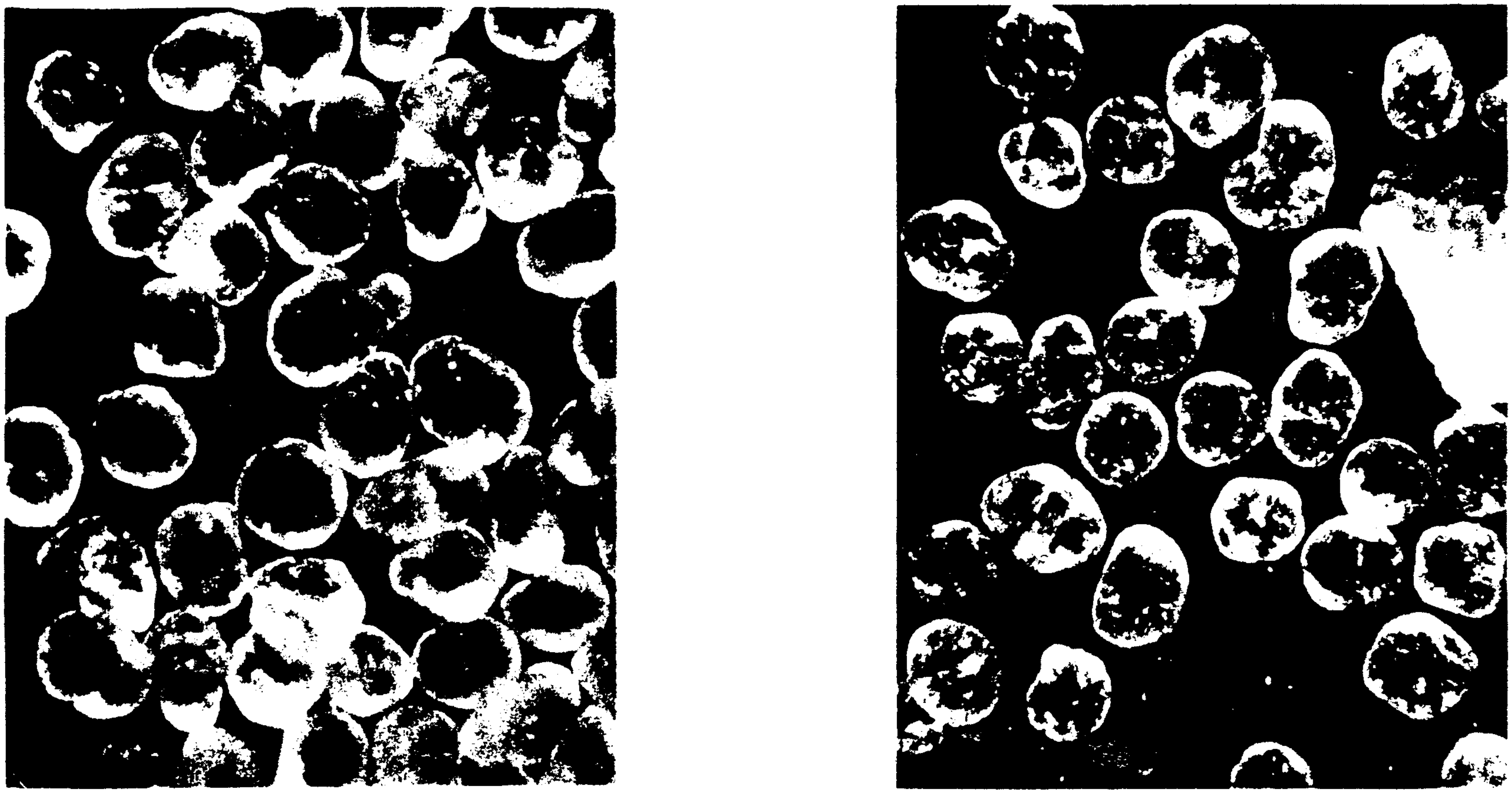
TABLE 2. SUMMARY OF MISSION/FLIGHT/SRM DESIGNATION, AP VENDOR, AND AVERAGE MIX CASTING TIME PER FLIGHT

Flight	Mission	SRM	AP Vendor	Average Mix Cast Time (min)
STS-8	8	8	KM	34.22
STS-9	41-A	9	PE	47.63
STS-11	41-B	10	KM	36.71
STS-13	41-C	11	PE	56.17
STS-14	41-D	13	KM	35.15
STS-17	41-G	12	PE	52.37
STS-19	51-A	14	PE	50.31
STS-20	51-C	15	KM	51.94
STS-23	51-D	17	KM	46.67
STS-24	51-B	16	PE	63.24
STS-25	51-G	18	PE	45.45
STS-26	51-F	19	KM	44.99
STS-27	51-I	20	PE	76.93
STS-28	51-J	21	PE	91.46
STS-30	61-A	22	PE	72.85
STS-31	61-B	23	PE	71.98
STS-32	61-C	24	KM	42.14
STS-33	51-L	25	PE	58.02
STS-34	61-E	26	PE	47.02
STS-35	61-F	28	PE	51.43
STS-36	61-G	27	KM	32.80

the cause of the crystal shape anomaly. The problem began with malfunctioning pumps and reduced cycling levels. These pumps circulate the crystals in solution to provide a smooth, homogeneous shape. Since the pump problem was identified and corrected, the crystal shape has returned to its normal condition.

3. Statistical Correlation Analysis

Because the viscosity problem was known to continue through several flights, MTI was requested to furnish MSFC with parametric data on the propellant characteristics. The vendor of AP for the next two flights following STS-28 (Mission 51-J) was PE. The third flight after STS-28 used AP from KM. The goal was to relate a measurable physical phenomena to changes in flight performance. MTI supplied several items of information including bulk density measurements, average end-of-mix viscosity, percent retention of AP on mesh screens, and average mix cast time (AMCT). This data was examined for relationships to the delivered total impulse gained through 20 sec (I_{20}). A direct measurement of flight data (head pressure) was substituted for thrust in the analysis to remove the uncertainty from reconstruction activities. The integral of head pressure through 20 sec is denoted by IP_{20}. After the thrust/pressure traces were normalized to the target burn rate to remove the effects of differing burn rates, the following results were observed:

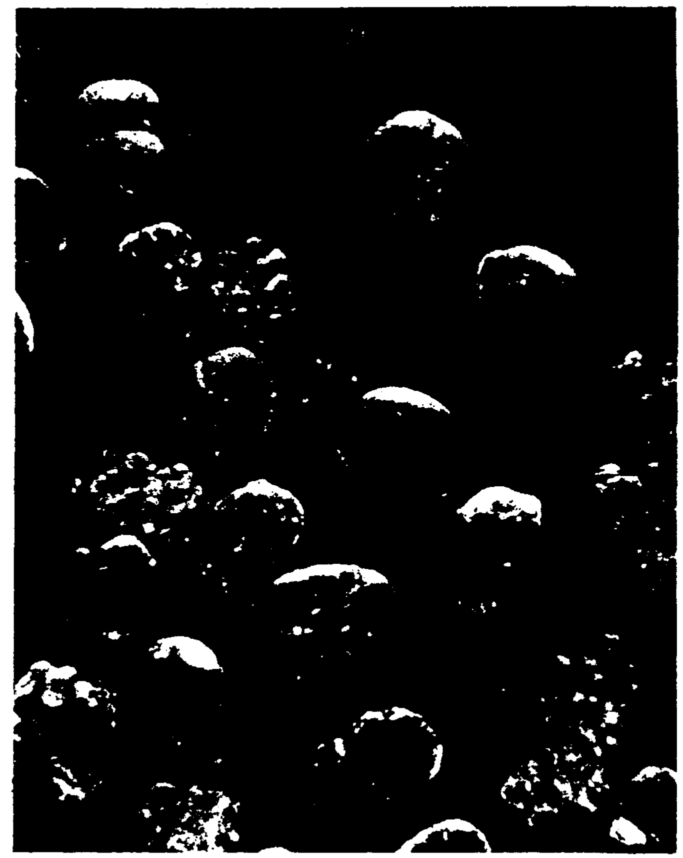


40X OF 70 MESH SCREEN

25X OF 40 MESH SCREEN

Figure 7. Photomicrographs of Kerr McGee AP.

40X OF 70 MESH SCREEN



25X OF 40 MESH SCREEN

Figure 8. Photomicrographs of Pacific Engineering AP.

a) The IP_{20} values are well correlated with AMCT for flights using SRMs manufactured using AP supplied by PE.

b) The range of AMCT values is sufficient to establish a correlation for PE SRMs.

c) The pattern of IP_{20} versus AMCT on PE SRMs explains the previous higher-than-normal value of SRM-16 used on STS-24 (Mission 51-B). This was the largest deviation from the 9-motor population average prior to STS-28 as shown on Figure 4.

d) The values of AMCT for flight sets using AP from PE begin decreasing after STS-28. This trend should lead to lower or normal values of IP_{20}.

e) The IP_{20} performance for flights is essentially normal when AP is supplied from KM. The AMCT values for KM propellant have little variation compared to PE.

f) The AMCT values for the AP supplied by PE returned to the normal range beginning with SRM-25 used on STS-33 (Mission 51-L). Table 2 shows satisfactory AMCTs for SRM-26/28 which were manufactured from AP supplied by PE.

Least square curve fit analyses were performed with respect to AMCT to predict the IP_{20} performance on subsequent flights. The correlations were updated following each flight using SRMs manufactured from AP supplied by PE. Curve fits of the head pressure integral at 20 sec (IP_{20}), large motor burn rate scale factor, and vacuum ISP are shown on Figures 9, 10, and 11, respectively. These correlations reflect the data gathered from flights through STS-32 (Mission 61-C). These least

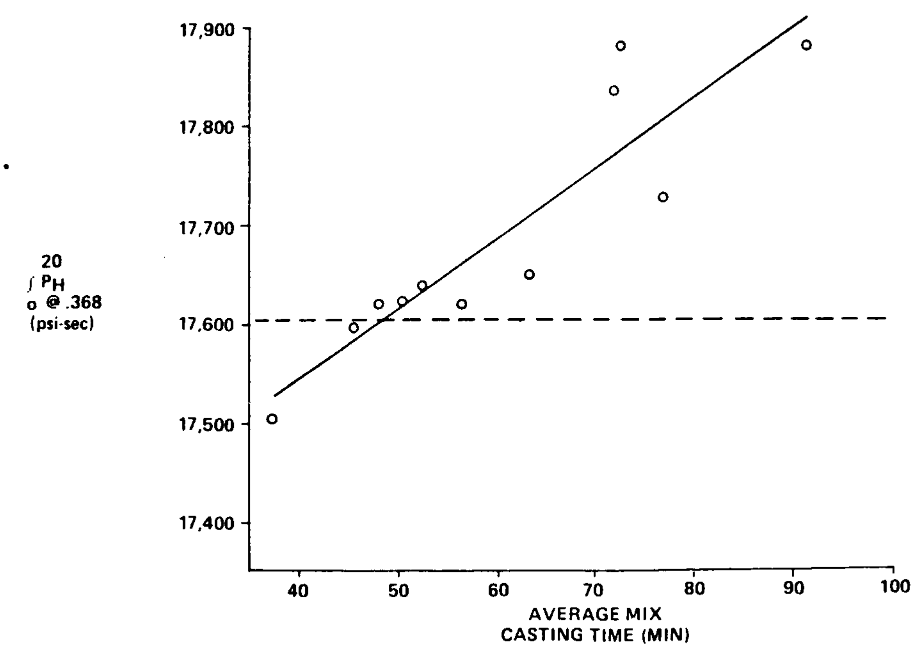


Figure 9. Flight average head pressure integrals at 20 sec for SRMs manufactured with Pacific Engineering AP (burn rate of 0.368 IPS, PMBT = 60°F).

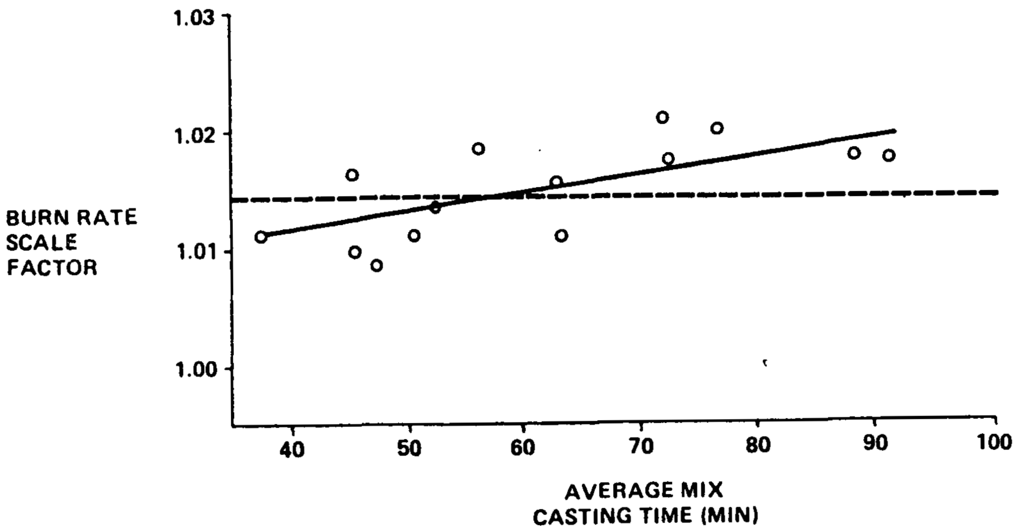


Figure 10. Flight average vacuum ISP for SRMs manufactured with Pacific Engineering AP.

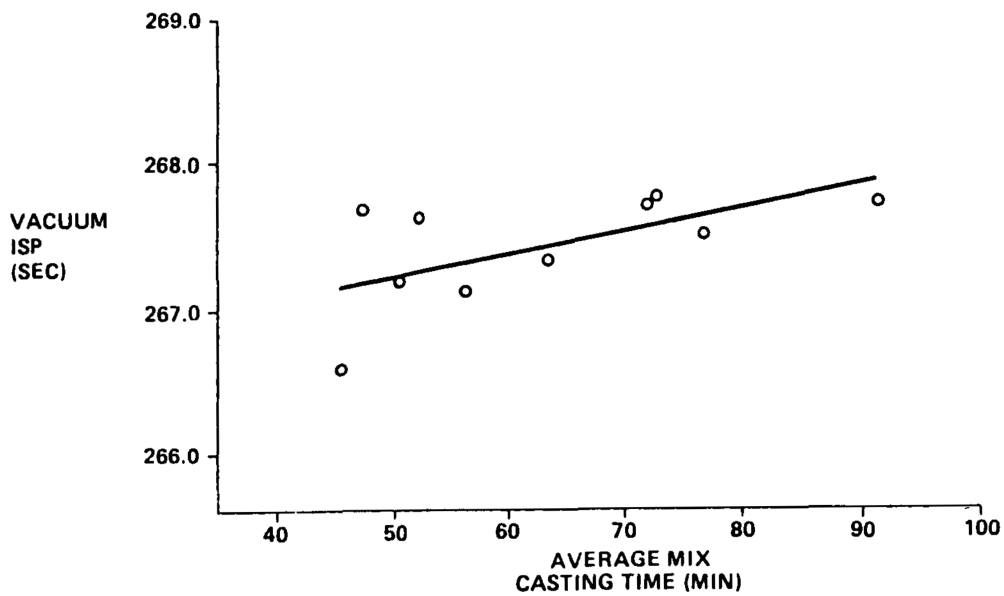


Figure 11. Flight average burn rate scale factors for SRMs manufactured with Pacific Engineering AP.

square correlations indicate trending because of the range of available data on AMCT. Ordinarily, the range of this data would be narrow and no trends could be observed. The probability of correlation for the integral of head pressure through 20 sec with respect to AMCT is greater than 99 percent.

D. STS-28 (Mission 51-J) BARF Curve Shift

The higher measured pressure from the SRMs on STS-28 indicates a change in the "hump" or "BARF" curve compared to curves generated from previous motor data. The "BARF" curve or burn augmentation rate factor curve accounts for non-homogeneous/non-theoretical burning of the SRM propellant. The shift of the "BARF" curve in the early part of burn is shown for STS-28 (Mission 51-J) on Figure 12. This indicates that the higher viscosity propellant particles are not dispersing during casting in the same pattern as previous motors.

The previous shift in the "hump" or "BARF" curve was observed on the QM-1 static test compared to the DM-1/2/3/4 experience with the standard motor. The QM-1 static test contained segments which, for the first time, were all cast with both a dispersion cone and an increased propellant casting rate requirement. These changes were implemented to preclude void or bubble formation during casting. This change was successful in eliminating voids, but the delivered thrust/pressure traces were permanently altered.

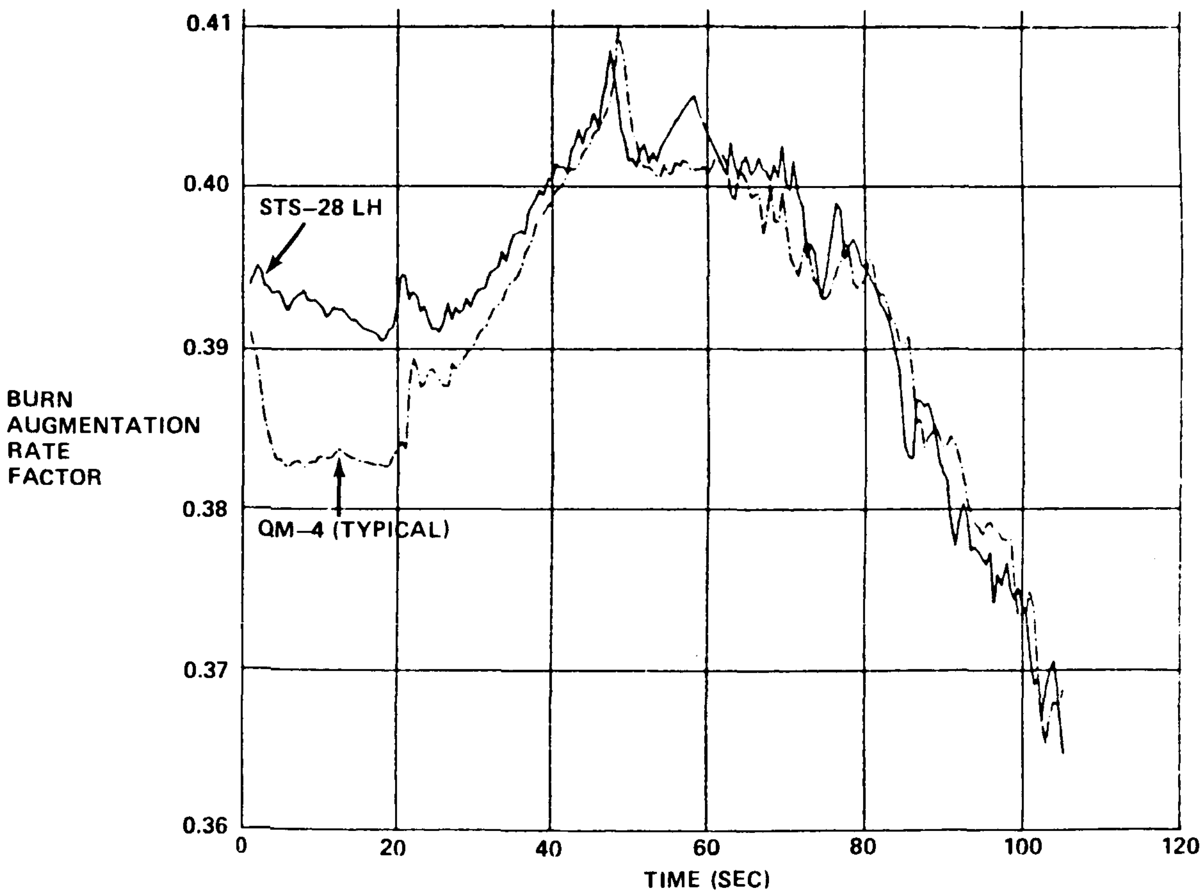


Figure 12. Comparison of BARF curve from STS-28 (Mission 51-J) left SRM to typical HPM curve (QM-4).

V. PERFORMANCE OF STS-30/31/32 (MISSIONS 61-A/B/C) AND SUBSEQUENT FLIGHTS

A. Discussion

Following the flight of STS-28 (Mission 51-J), JSC requested predictions of how the following flights would perform. The flight planners wanted to know if the prediction should be revised or if the observed shift in performance would continue or get worse. The next flight was STS-30 (Mission 61-A) which also used SRMs manufactured from AP supplied by PE. Based upon our correlations with AMCT, predictions were provided for the expected performance from the higher viscosity propellant.

B. Prediction and Evaluation of STS-30 (Mission 61-A)

The flight of STS-30 (Mission 61-A) utilized the SRM set designated as SRM-22. The SRMs were manufactured using AP supplied by PE. The AMCT for these SRMs was 72.85 min. The official predictions using the block model for STS-30 are documented in [3]. This prediction assumed no effect from AMCT. This prediction was supplemented with a subsequent assessment of high thrust in the first 20 sec. The evaluation of the causes for high thrust/pressure shape and burn rate through the flights of 51-I/J and the prediction of the effect on STS-30 are documented in [4]. The STS-30 performance in the first 20 sec was predicted using the postulated AMCT relationship based upon nine samples to be ∿0.70 percent higher than the normal prediction. This predicted variation would be well within the ±3 percent allowable variation from nominal. The flight burn rates were also predicted using the AMCT relationship to be ∿0.20 percent higher than usually predicted. The postflight evaluation shows that STS-30 performed ∿1.60 percent higher than normally predicted. The actual burn rates were ∿0.32 percent over the normal burn rate prediction. The "BARF" curve shift was similar to the STS-28 (Mission 51-J) shift.

C. Prediction and Evaluation of STS-31 (Mission 61-B)

The flight of STS-31 (Mission 61-B) utilized the SRM set designated as SRM-23. The SRMs were manufactured using AP supplied by PE. The AMCT for SRM-23 was 71.98 min. The official predictions using the block model for STS-31 are documented in [5]. This prediction assumed no effect from AMCT. This prediction was again supplemented with an assessment of high thrust in the first 20 sec. This assessment was updated to include the data gained from STS-30 and is documented in [6]. The STS-31 performance in the first 20 sec was predicted using the AMCT relationship to be ∿0.90 percent higher than normal. This prediction of higher-than-normal performance was again within the ±3 percent allowable variation. The flight burn rates were also predicted to be ∿0.22 percent higher than usually predicted. The postflight evaluation shows that STS-31 performed ∿1.34 percent higher than normally predicted. The actual burn rates were ∿0.61 percent over the normal burn rate prediction. The "BARF" curve shift was significant but less than experienced on STS-28/30.

D. Prediction and Evaluation of STS-32 (Mission 61-C)

The flight of STS-32 (Mission 61-C) utilized the SRM set designated as SRM-24. The SRMs were manufactured using AP supplied by KM. The previous four flights used SRMs manufactured from AP supplied by PE. The official predictions using the block model for STS-32 are documented in [7]. Since SRM-24 was manufactured from AP supplied by KM, the performance was predicted to be essentially normal. No effects from viscosity should appear. The postflight evaluation shows that STS-32 performed only ∿0.23 percent higher than normally predicted. The actual burn rates were ∿0.07 percent lower than predicted. The "BARF" curve was not shifted as was seen on STS-28/30/31. This confirmed our prediction that the high thrust previously experienced, would disappear when AP was supplied by KM.

E. Subsequent Flights

Beginning with the seventeenth batch of raw materials supplied to MTI from PE, the AMCT returned to its normal level. This AP and subsequent batches were used to manufacture QM-5 and SRM-25/26/28, respectively. The history of AMCT for the PE and KM vendors is shown on Figure 13. The average AMCT for the KM vendors is 42.1 min with a standard deviation of 0.14 percent. The average AMCT for the PE vendor prior to SRM-20 used for STS-27 (Mission 51-I) was 50.6 min with a standard deviation of 0.16 percent. The average AMCT beginning with QM-5 (production batch number 17) through the manufacture of SRM-28 (production batch number 20) is 49.8 min with a standard deviation of 0.13 percent. This data indicates that subsequent flights whether using AP supplied by either KM or PE should have normal variations in thrust-time and burn rate if no other variations intervene.

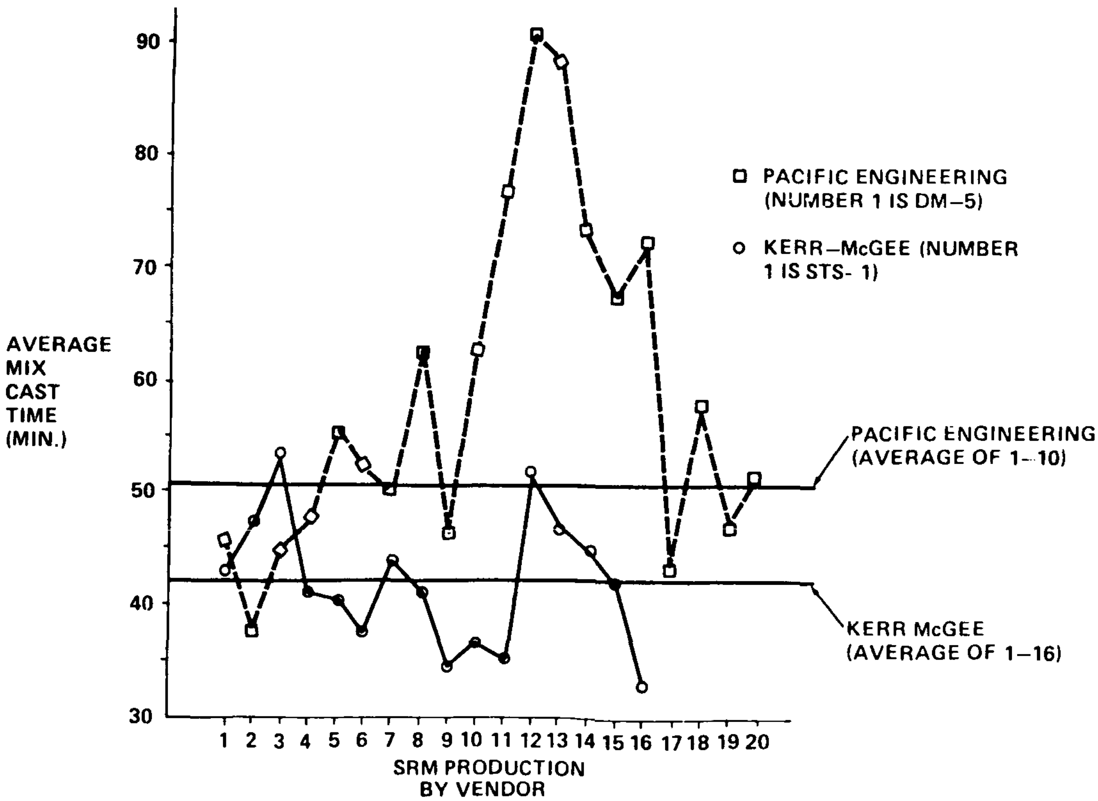


Figure 13. Average mix cast time for SRMs produced by AP vendor.

VI. CONCLUSIONS

Beginning with the flight of STS-27/28 (Missions 51-I/J) and continuing on the flights of STS-30/31 (Missions 61-A/B), the Shuttle SRM performance reproducibility experienced a transient phenomena. The performance delivered through 20 sec by the SRMs on these flights was much higher than normally expected. The values for burn rates and vacuum Isp were also affected. This unexpected high performance caused much concern among the flight planning community.

The cause of the shift in performance has been correlated to the more viscous propellant used on the flights. This propellant was manufactured using AP supplied by Pacific Engineering. The increased viscosity resulted from a change in the AP crystal shape which occurred simultaneously with the onset of the performance differences. The supplier of AP crystals has corrected the problem. The AMCT has returned to normal.

The performance changes which might be expected from this shift in propellant raw materials have not been identified previously. The parameter (AMCT) will be monitored in the future to predict new trends which may cause performance to be different than predicted.

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APPROVAL

SHIFTS IN SHUTTLE SRM PERFORMANCE BECAUSE OF
AMMONIUM PERCHLORATE CRYSTAL SHAPE
ON MISSIONS 51-I/J AND 61-A/B

By Douglas L. Blackwell

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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16. ABSTRACT

The design of the Space Shuttle vehicle configuration requires that the SRMs produce thrust within tightly-controlled limits. These limits provide assurance that Shuttle ascent performance goals will be achieved within the vehicle flight load constraints. The SRM's will perform within these limits if overall SRM reproducibility is maintained. This report will initially describe the excellent performance reproducibility of the 24 SRMs during the first 12 flights [STS-8 through STS-26 (Mission 51-F)] using the HPM SRM. Secondly, this report will describe the transient phenomena which interrupted the reproducibility in the first 20 sec of flight for four flights (Missions 51-I/J and 61-A/B). The cause of this 20 sec phenomena is postulated to be a change in the crystal shape of the ammonium perchlorate used in the propellant. This shape change coincided with the performance shift on these four flights. The ballistic effect of the crystal shape change is manifested as a change to the generic "HUMP" or "BARF" curve of the Shuttle SRM thrust/pressure-time curve. As the crystal shape change was corrected by the vendor, the performance produced by the Shuttle SRM returned to normal.

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